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(54) **PAIN INFERRING DEVICE AND PAIN INFERRING METHOD**

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(51) **Int. Cl.**[7] **A61B 5/00**

(52) **U.S. Cl.** **600/300**

(58) **Field of Search** 600/300, 301, 600/587, 592, 595–597; 482/79, 34; 128/920; 400/489; 364/508

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(57) **ABSTRACT**

A pain inferring device for designing a shape giving a subject as little pain as possible when the subject touches the shape. The pain inferring device includes an input unit, an output unit, a main control unit, a learning storage unit, and a neural network. The neural network learns the relationship between the input value of shape data and the output value of the data on the degree of pain when a subject touches a shape. By the learning, an input/output function (namely, the coefficient of coupling of neurons in layers) representing the relationship between the input and output values is defined and stored in the learning storage unit. When the shape data is inputted through the input unit, the neural network infers the degree of pain by using the function stored in the learning storage unit.

4 Claims, 3 Drawing Sheets

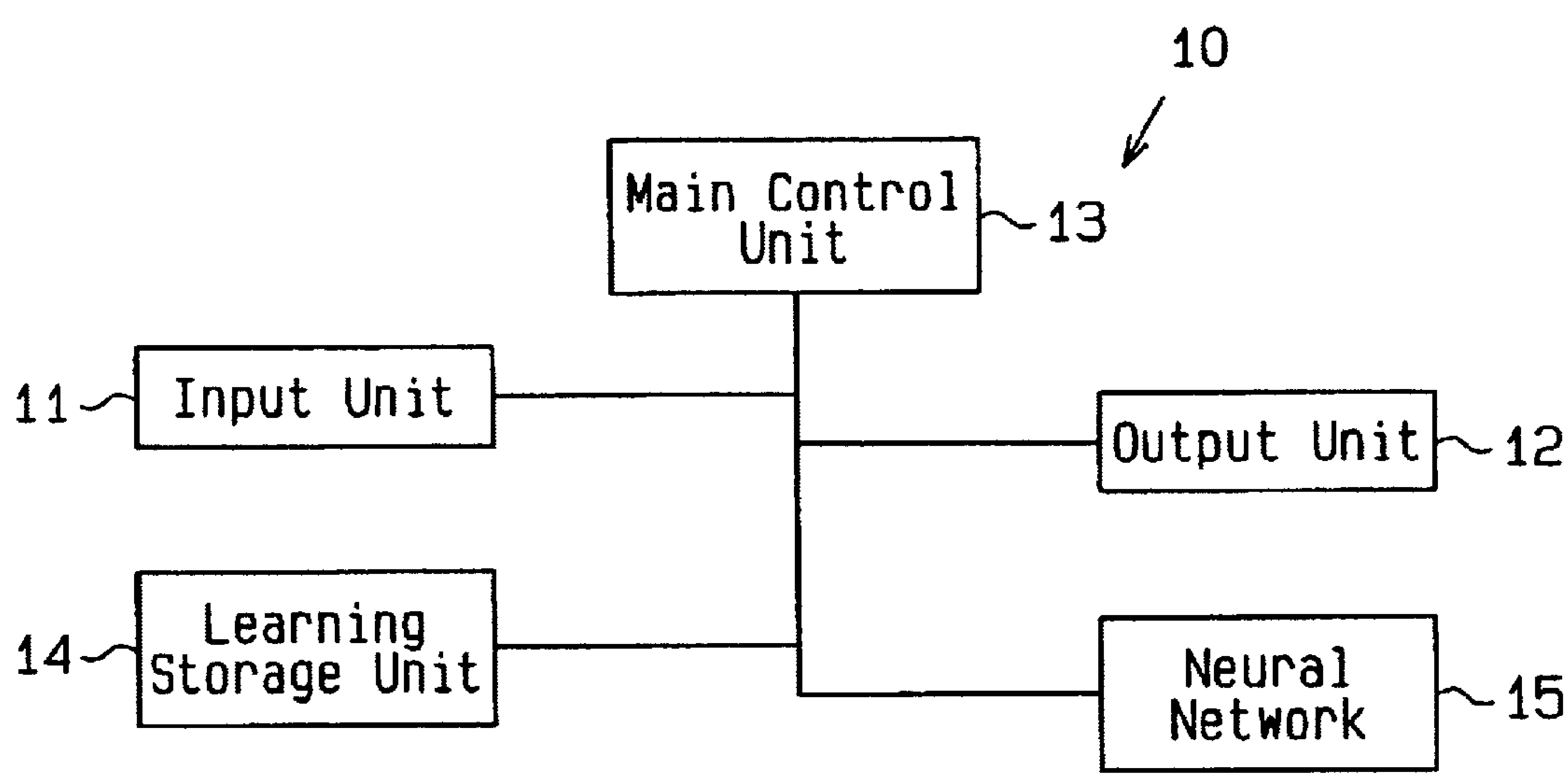


Fig.1

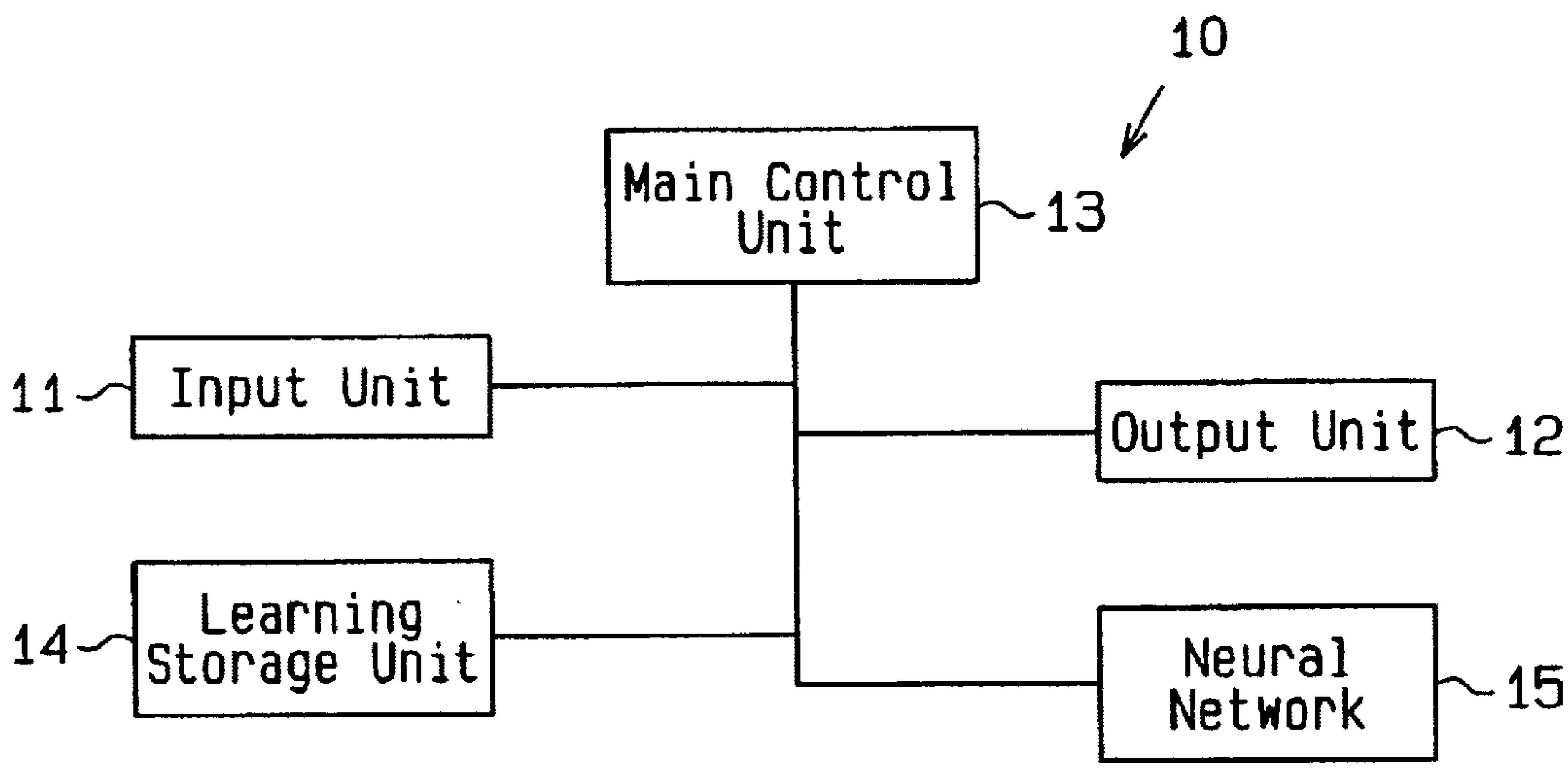

10
Main Control Unit
13
11
Input Unit
Output Unit
12
14
Learning Storage Unit
Neural Network
15

Fig.2

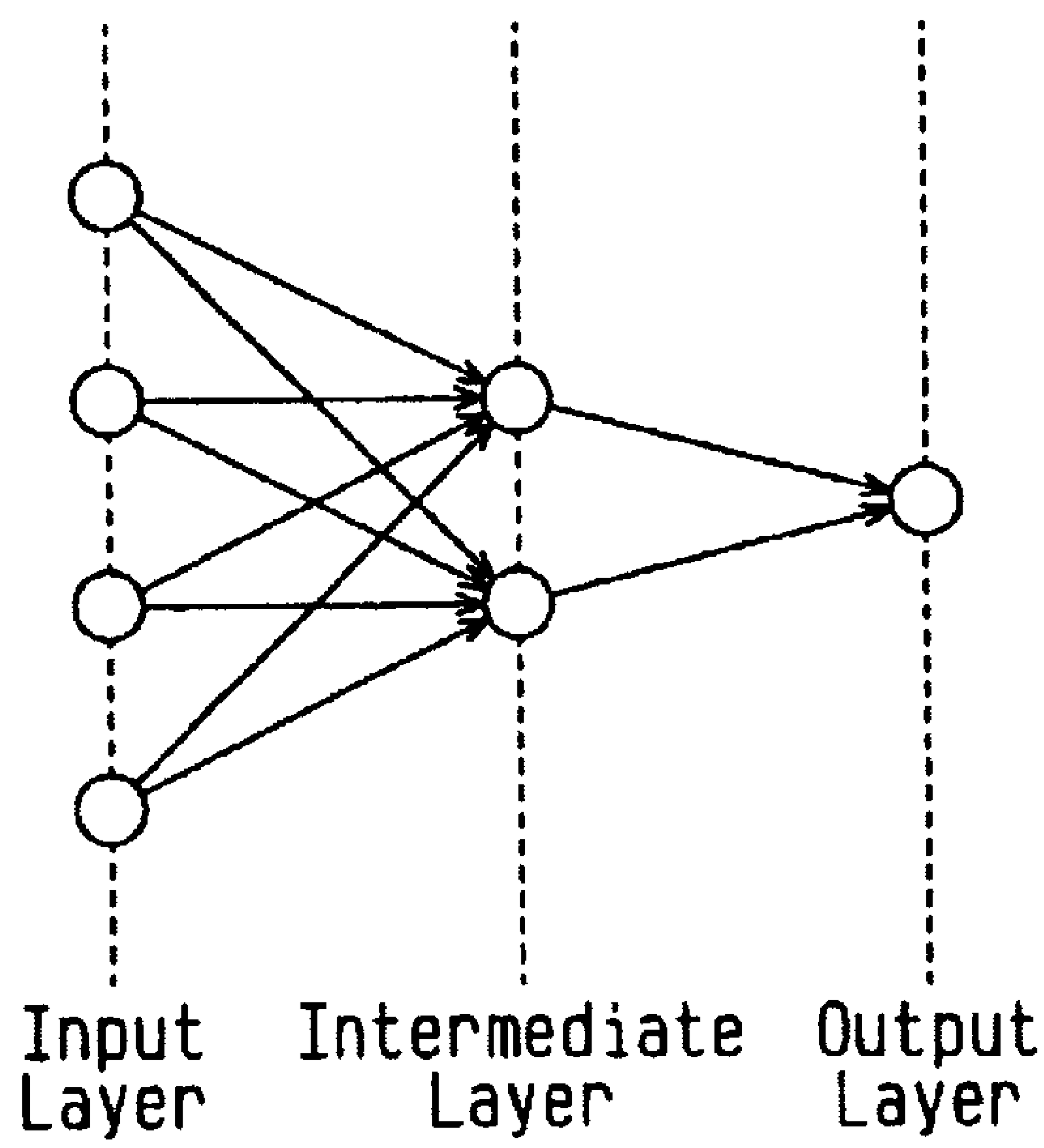

Input Layer
Intermediate Layer
Output Layer

Fig.3

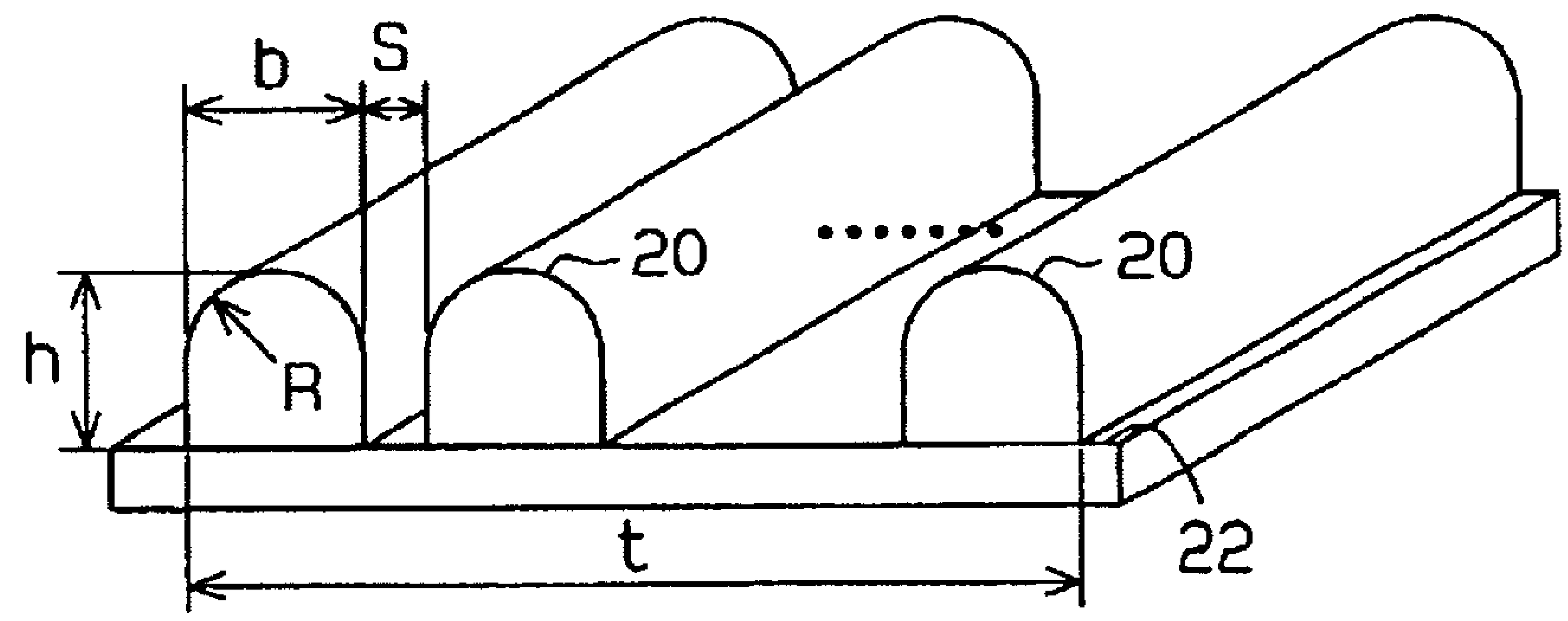


Fig.4

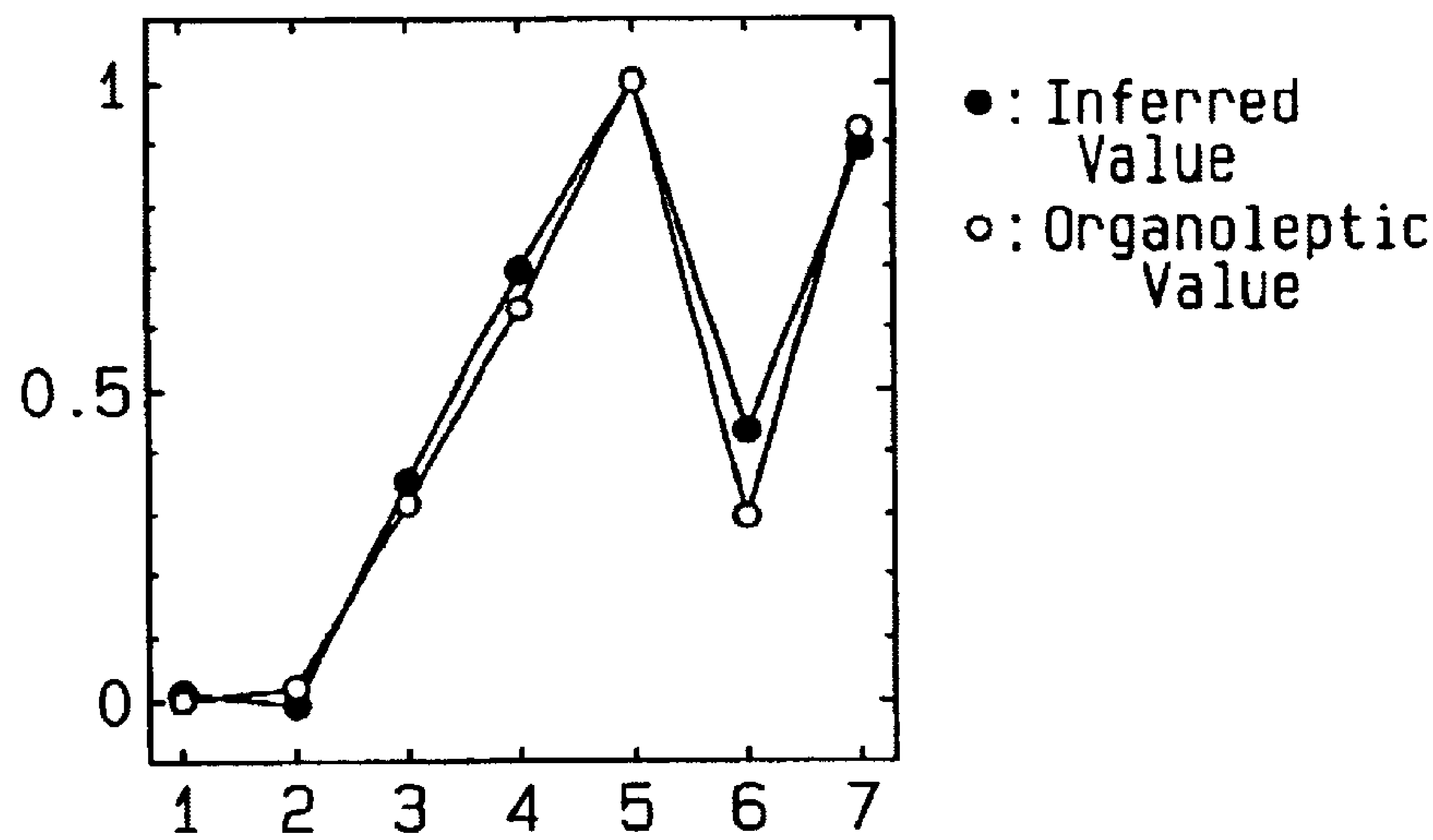


Fig.5

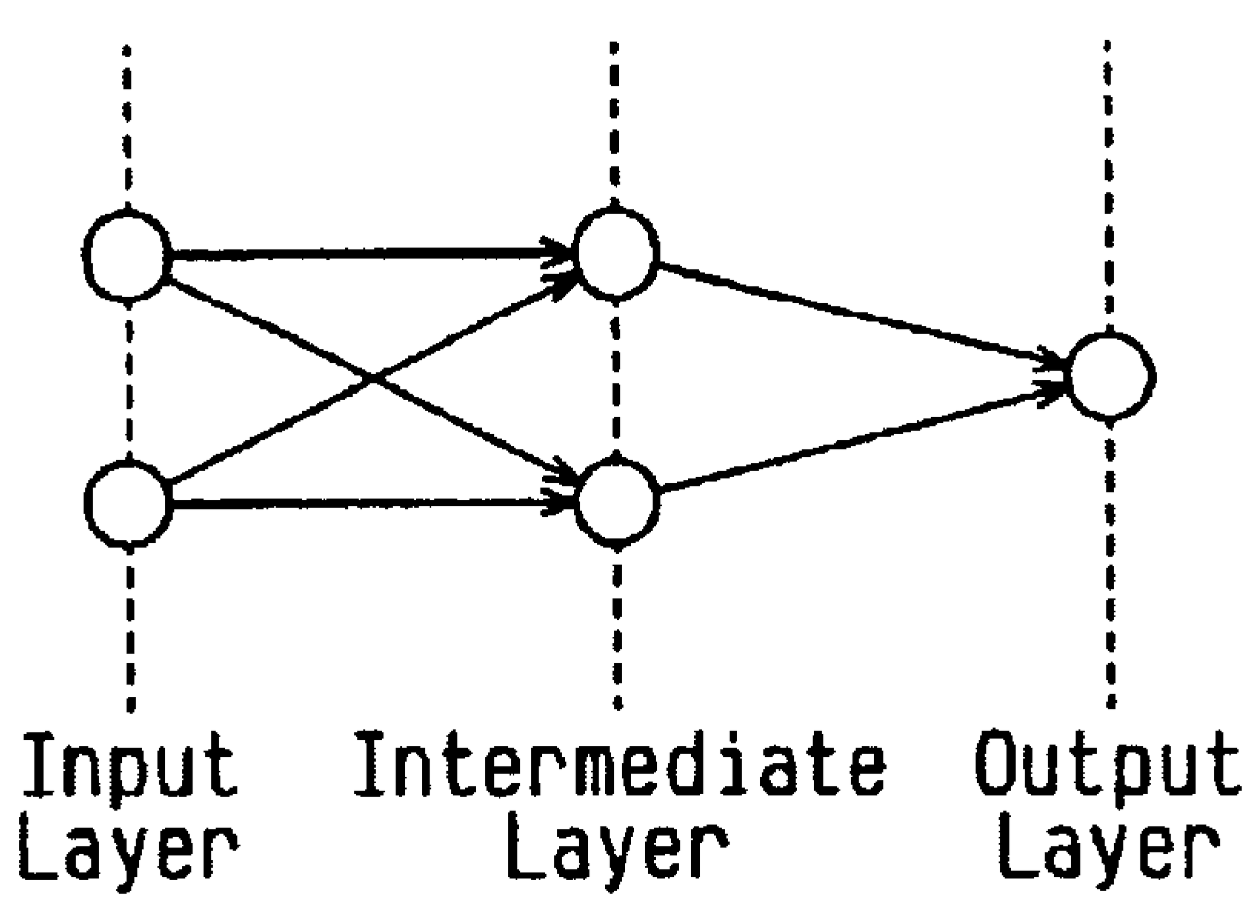


Fig.6

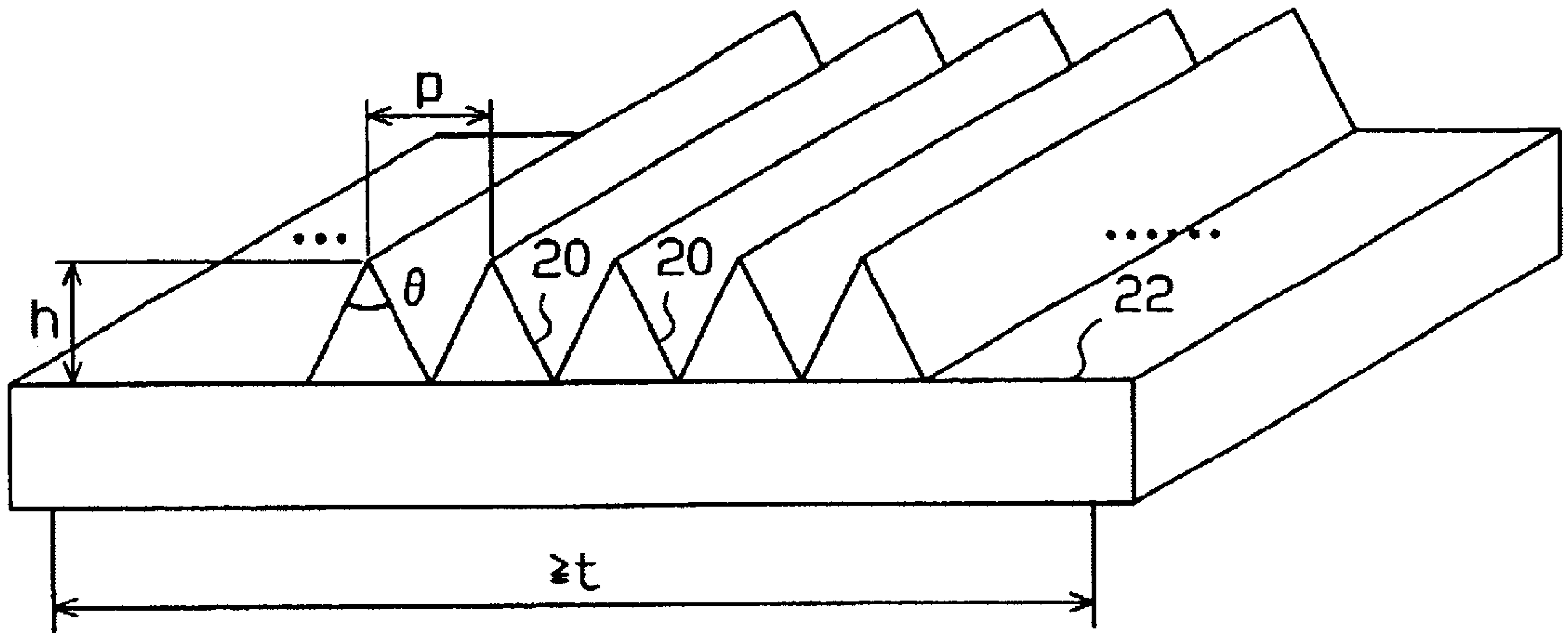
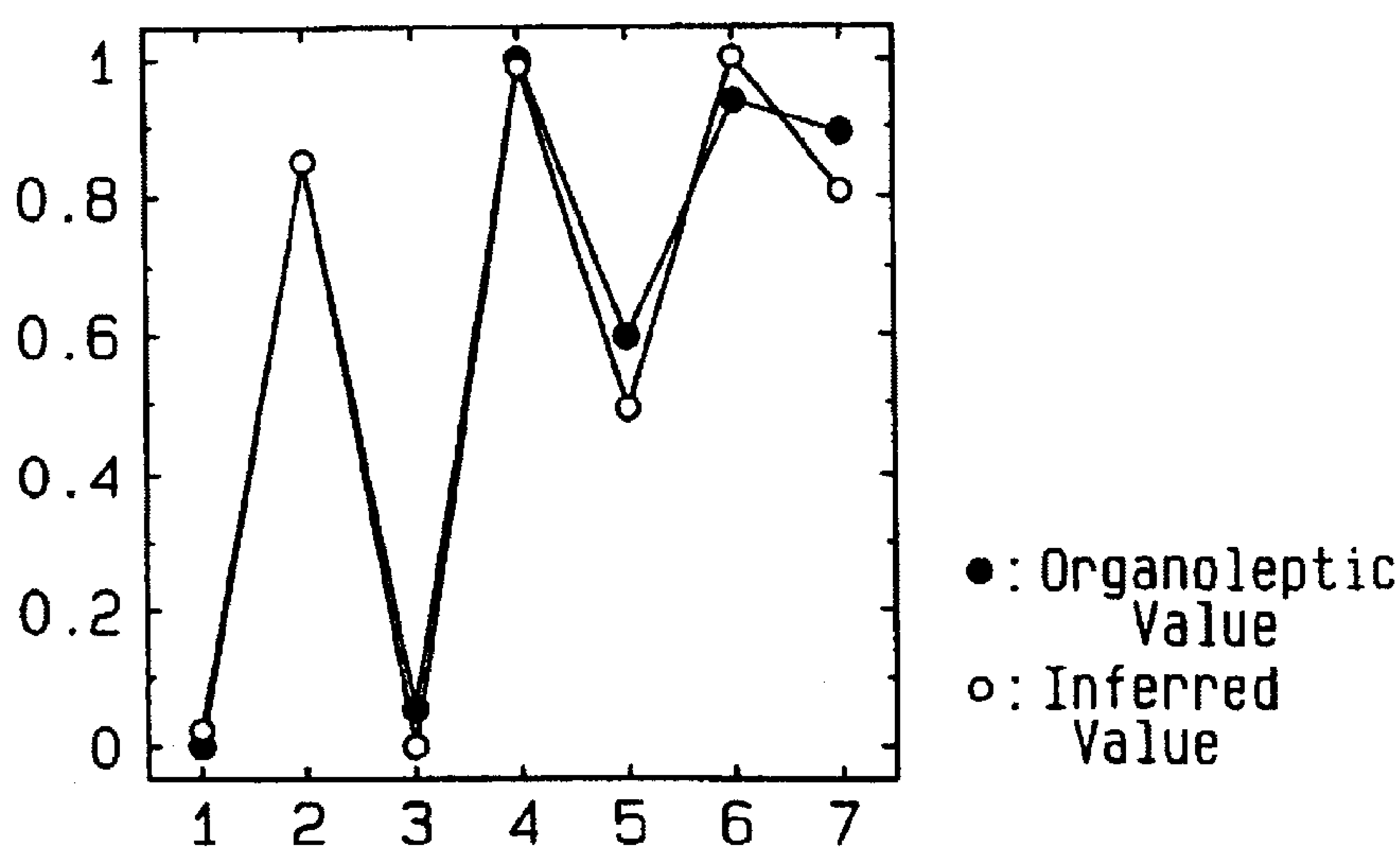

p
h
θ
20
20
22
≧t

Fig.7


1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
●: Organoleptic Value
○: Inferred Value

PAIN INFERRING DEVICE AND PAIN INFERRING METHOD

TECHNICAL FIELD

The present invention relates to a pain inferring device, more specifically to a pain inferring device for inferring a pain felt by a person when he or she touches a certain shape.

BACKGROUND OF THE INVENTION

BACKGROUND ART

Taking a switch for example, operating portion thereof is formed to have an uneven surface so as to prevent slipping of operators' fingers during operation. However, operators are likely to feel pain depending on the shape of the uneven surface or on the manner of operating the switch.

Evaluation of the degree of pain in operators has conventionally been practiced by preparing, at the stage of designing an operating portion, those having various types of uneven surface profiles and allowing test subjects to operate the operating portions thus prepared. An optimum shape is then selected based on evaluation of the degree of pain or on measurement to prepare an operating portion giving minimized pain to operators. However, in order to obtain subjective evaluation of degrees of pain by test subjects, there are prepared a number of operating portions, at the stage of designing, so that it takes much time and labor. Thus, it is difficult to easily set out at the stage of designing an operating portion giving as little pain as possible.

BRIEF SUMMARY OF THE INVENTION

DISCLOSURE OF THE INVENTION

It is an object of the present invention to provide a pain inferring device and a pain inferring method capable of designing easily a shape giving minimized pain.

According to one aspect of the present invention, there is provided a pain inferring device. The pain inferring device includes input means, learning means and function storage means. The input means inputs shape data for specifying a shape. The learning means learns the relationship between the shape data as an input and a degree of pain, as an output, felt by a person when he or she touches the shape corresponding to the shape data to produce an input-output function indicative of the relationship between the input and the output. The function storage means stores the input-output function. As soon as the shape data are inputted through the input means, the learning means infers the degree of pain based on the input-output function stored in the function storage means.

According to another aspect of the present invention, there is provided a pain inferring method. The pain inferring method includes the steps of learning a relationship between shape data as an input and a degree of pain, as an output, felt by a person when he or she touches the shape corresponding to the shape data; producing an input-output function indicative of the relationship between the input and the output; and inferring based on an input of new shape data a degree of pain according to the input-output function.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

FIG. **1** is a schematic block diagram of a pain inferring device according to one embodiment of the present invention;

FIG. **2** is a schematic diagram of a neural network of the pain inferring device of FIG. **1**;

FIG. **3** is a schematic diagram of a test piece having a surface profile similar to that of a switch knob;

FIG. **4** is a graph showing the relationship between each test piece and the degree of pain in an inferred pain verification test;

FIG. **5** is a schematic diagram of a neural network of the pain inferring device according to a second embodiment of the present invention;

FIG. **6** is a schematic diagram of a test piece having a surface profile similar to that of a switch knob; and

FIG. **7** is a graph showing the relationship between each test piece and the degree of pain in an inferred pain verification test.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A pain inferring device **10** according to a first embodiment of the present invention will be described below referring to FIGS. **1** to **4**.

As shown in FIG. **1**, the pain inferring device **10** is provided with an input unit **11**, an output unit **12**, a main control unit **13**, a learning storage unit **14** and a neural network **15**. The main control unit **13** is connected to the input unit **11**, the output unit **12**, the learning storage unit **14** and the neural network **15**. The input unit **11** consists essentially of a keyboard and the like and is used by operators for inputting numerical data including shape data etc. The main control unit **13** includes a central processing unit (CPU), which performs data processing and control of the input unit **11**, the output unit **12**, the learning storage unit **14** and the neural network **15**. The output unit **12** includes a printer and/or a display unit, which outputs data (inferred value) indicative of the degree of pain under control by the main control unit **13**.

The neural network **15** functions as learning means and is preferably a hierarchical neural network having an input layer, an intermediate layer and an output layer, each layer including a multiplicity of neurons. The coefficients of coupling between neurons of the input layer and those of the intermediate layer and between neurons of the intermediate layer and that of the output layer are learned preferably in accordance with the known back-propagation algorithm. Here, the back-propagation algorithm may be replaced with any other learning algorithms, so long as its accuracy is permissible. Learning by the neural network **15** will be described later.

The learning storage unit **14**, which is preferably a non-volatile semiconductor memory, stores information including the number of layers in the neural network **15**, the number of synapses connecting the neurons of the respective layers and coefficients of coupling between the synapses. The information stored in the learning storage unit **14** is handled as an input-output function governing the relationship between the input values and the output value.

The pain inferring device **10** is used, for example, for designing a switch knob (not shown) having a surface profile similar to that of a test piece **22** as shown in FIG. **3**. The test piece **22** has on the surface thereof a plurality of ribs **20** arranged parallel to one another.

(Shape Data Setting)

Shape data (hereinafter referred to as shape variables) of the ribs **20** include the height h, the rib-to-rib pitch S, the radius of curvature R at the crest of the rib **20** and the width b of the rib **20**. The shape variables are set based on the case where the ribs **20** are formed on a test piece **22** having a length t (30 mm, in this embodiment). Data of nine types of test pieces having ribs **20** with different shape variables are shown in Table 1.

TABLE 1

Test piece no.	1-1	1-2	1-3	1-4	1-5	1-6	1-7	1-8	1-9
H	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
B	1.0	1.5	2.0	1.0	1.5	2.0	1.0	1.5	2.0
R	0.0	0.3	0.5	0.3	0.5	0.0	0.5	0.0	0.3
S	0.5	1.0	1.5	1.5	0.5	1.0	1.0	1.5	0.5

(unit: mm)

(Pain Evaluating Test)

There were provided test pieces **22** based on the nine types of data shown in Table 1, and a pain evaluating test (organoleptic test) was performed using five adult males as test subjects.

Evaluation of pain is performed by calculating the absolute evaluation point using the known Scheffe's paired comparison method (variation of the Haga's method). According to the paired comparison method, each test subject places his or her fingers on a pair of test pieces fixed parallel to each other, and in this state the test pieces are drawn back horizontally from the test subject. The test subject evaluates degrees of pain felt by himself or herself at that moment according to the 7-point rating method (rating in the range of 0±3, by an increment or decrement of 0.5 point) (see "Degree of pain before normalization" in Table 2).

Mean values of these evaluation points for the test pieces are calculated and normalized, respectively. Here, normalization of the mean values is performed as follows:

First, the maximum theoretical value A of the absolute evaluation point is determined according to the following equation (1):

$$A=\alpha\times(\text{Number of samples evaluated}-1)/\text{Number of samples evaluated} \quad (1)$$

wherein α represents the maximum value of the relative evaluation point. Here, the minimum theoretical value is also determined. Approximate values 1 and 0 are set referring to the maximum theoretical value A and the minimum theoretical value of the absolute evaluation point obtained according to the above equation (1) to perform normalization based on the approximate values 1 and 0.

It should be noted here that, in this test, nine test pieces were used as samples to be evaluated, so that the maximum theoretical value and the minimum theoretical value were calculated to be 2.67 and −2.67 according to the above equation (1), and the approximate values of the maximum value and the minimum value were set at 2.5 and −2.5, respectively, to perform normalization based on these values. Degrees of pain before and after normalization are shown below in Table 2.

TABLE 2

Test piece no.	1-1	1-2	1-3	1-4	1-5	1-6	1-7	1-8	1-9
Degree of pain before normalization	−1.42	−0.04	0.53	1.11	−0.11	−0.80	1.69	−0.07	−0.89
Degree of pain after normalization	0.22	0.49	0.61	0.72	0.48	0.34	0.84	0.49	0.32

The evaluation point xijl of the assay test piece (one test piece of the two) in comparison with the reference test piece (the other test piece of the two) is assumed according to the following equation (2)

$$xijl=(\alpha i-\alpha j)+gij+eijl \quad (2)$$

In the above equation,

i: assay test piece no.;

j: reference test piece no.;

αi: absolute evaluation point of i;

αj : absolute evaluation point of j;

gij: effect to be exhibited by the combination of reference test piece and assay test piece;

l: test subject no.; and

eijl: error of test subject

The effect gij to be exhibited by the combination of the reference test piece and the assay test piece is a psychological afterimage effect of evaluation of the previous test piece on the evaluation of the subsequent test piece. Thus, absolute evaluation point αi of each test piece is calculated according to the equation (2).

(Learning by Pain Inferring Device **10**)

The shape variables as input values and the absolute evaluation point αi as an output value are inputted through the input unit **11** of the pain inferring device **10** to allow the neural network **15** to learn the relationship between the input and the output. The neural network **15**, which is of 4-input and 1-output system, includes an input layer, an intermediate layer and an output layer, as shown in FIG. **2**, and learns according to the back-propagation algorithm. The intermediate layer has two elements (neurons). Before inputting to the input unit **11**, the input values and the output value are normalized such that they have a maximum value of 0.95 and a minimum value of 0.05. The learning by the neural network **15** is terminated when the error of the output value reduces to a tolerable level of 0.01 or less. The input-output function governing the learned relationship between the input and the output is stored in the learning storage unit **14**. It should be noted here that, referring to the degree of pain, the greater the numerical value, the greater the degree of pain, whereas the smaller the numerical value, the smaller the degree of pain. If shape variables are input to the pain inferring device **10** after completion of learning, the device **10** can infer the degree of pain to be given by the shape corresponding to the shape variables.

(Inferred Pain Verification Test)

The degree of pain inferred, after completion of learning, by the pain inferring device **10** (inferred value) was compared with degrees of pain reported by a plurality of (in this embodiment, five adult males) test subjects as the result of an organoleptic test (organoleptic values).

In the verification test, there were prepared seven test pieces each having a shape according to shape variables, which are different from those used in the pain evaluating test. Each test piece was subjected to organoleptic test, whereas the shape variables were input to the pain inferring device **10** to determine the degree of pain. In the pain inferring device **10**, as soon as the shape variables are input thereto, the neural network **15** supplies the degree of pain in accordance with the input-output function stored in the learning storage unit **14** to the main control unit **13**. In the organoleptic test, degrees of pain were determined according to the equation (2) to calculate a mean value like in the pain evaluating test.

Table 3 shows shape variables of each test piece, and Table 4 shows an inferred value as the degree of pain in each test piece measured by the pain inferring device **10** after learning and a normalized value of the degree of pain in each test piece evaluated by the organoleptic test (organoleptic value). Here, the normalization was performed such that the maximum value and the minimum value before normalization are set at 1 and 0 respectively.

TABLE 3

Test piece no.	1-10	1-11	1-12	1-13	1-14	1-15	1-16
H	1.5	1.5	1.5	1.5	1.5	0.5	0.5
B	1.5	2.0	2.0	1.0	1.0	1.0	1.0
R	0.0	0.0	0.5	0.5	0.5	0.0	0.5
S	0.5	0.5	0.5	0.5	1.5	1.5	1.5

(unit: mm)

TABLE 4

Test piece no.	1-10	1-11	1-12	1-13	1-14	1-15	1-16
Degree of pain (organoleptic value)	0.00	0.02	0.31	0.63	1.00	0.29	0.92
Degree of pain (inferred value)	0.01	0.00	0.34	0.69	1.00	0.43	0.89

FIG. **4** is a graph showing the relationship between each test piece and the degree of pain in the inferred pain verification test.

As is clear from FIG. **4**, there was obtained a result that the inferred values as the degrees of pain measured by the pain inferring device **10** substantially coincide respectively with the organoleptic values obtained as the degree of pain in the organoleptic test.

(Second Embodiment)

Next, the pain inferring device according to a second embodiment of the present invention will be described referring to FIGS. **5** to **7**.

The pain inferring device **10** of the second embodiment is provided with an input unit **11**, an output unit **12**, a main control unit **13**, a learning storage unit **14** and a neural network **15**. The neural network **15** in the second embodiment is of 2-input and 1-output system and includes an input layer, an intermediate layer and an output layer, as shown in FIG. **5**. The intermediate layer has two elements (neurons).

The pain inferring device **10** of the second embodiment is suitable for designing a switch knob (not shown) having a serrated surface, as shown in FIG. **6**. In other words, a plurality of ribs **20** each having a triangular cross section are formed parallelwise on the surface of a test piece **22** in the second embodiment.

(Shape Data Setting)

Shape variables of the ribs **20** include the height h and the apex angle θ thereof. The shape variables are set based on the case where the ribs **20** are formed on a test piece **22** having a length t (30 mm, in this embodiment). Data of seven types of test pieces having ribs **20** with different shape variables are shown in Table 5.

TABLE 5

Test piece no.		2-1	2-2	2-3	2-4	2-5	2-6	207
Before normalization	h (mm)	0.5	0.5	1.0	1.0	1.0	1.5	1.5
	θ (deg)	62	152	74	103	136	62	152
After normalization	h	0.05	0.05	0.50	0.50	0.50	0.95	0.95
	θ	0.05	0.05	0.17	0.46	0.50	0.05	0.95

(Pain Evaluating Test)

A pain evaluating test (organoleptic test) was performed using five adult male test subjects like in the first embodiment for seven test pieces **22**. The results are shown in Table 6.

In the method of normalizing mean values in the second embodiment, the maximum theoretical value and the minimum theoretical value of the absolute evaluation point were determined according to the equation (1), and the approximate values 1 and 0 were set referring to the maximum theoretical value and the minimum theoretical value to perform normalization.

In the organoleptic test, seven test pieces are used as samples to be evaluated, so that there are obtained the maximum theoretical value 2.5 and the minimum theoretical value −2.5 according to the equation (1). However, if the above maximum theoretical value and the minimum theoretical values are used, the data are very likely to concentrate. Therefore, normalization was performed employing a maximum value of 1.5 and a minimum value of −1.5 therefor.

TABLE 6

Test piece no.	2-1	2-2	2-3	2-4	2-5	2-6	2-7
Degree of pain before normalization	−1.37	−0.49	0.26	0.77	0.37	0.89	−0.43
Degree of pain after normalization	0.04	0.34	0.59	0.76	0.62	0.80	0.36

(Learning by Pain Inferring Device **10**)

The shape variables (normalized values) shown in Table 5 as input values and the absolute evaluation point αi as an output value were inputted through the input unit **11** of the pain inferring device **10** to allow the neural network **15** to learn the relationship between the input and the output. The neural network **15** in the second embodiment learned according to the back-propagation algorithm. The input values and the output value were normalized such that they have the maximum value of 0.95 and the minimum value of 0.05, and the learning by the neural network **15** was terminated when the error of the output value reduced to a tolerable level of 0.01 or less. If shape variables of a certain serrated shape are inputted to the pain inferring device **10** after completion of learning, the device **10** infers the degree of pain to be given by the shape corresponding to the shape variables.

(Inferred Pain Verification Test)

After completion of learning, the inferred values as the degrees of pain measured by the pain inferring device **10** were compared with the degrees of pain reported by a plurality of (in this embodiment, five adult males) test subjects as a result of an organoleptic test (organoleptic values). In the verification test, there were prepared test pieces each having a shape according to shape variables which are different from those used in the pain evaluating test, to obtain organoleptic values as the degrees of pain to be given by the test piece evaluated by the organoleptic test and inferred values as the degrees of pain measured by the pain inferring device **10**. The organoleptic values as the degrees of pain in the organoleptic test were calculated according to the equation (2).

Table 7 shows shape variables of each test piece before and after normalization respectively. Table 8 shows inferred values obtained as the degrees of pain given by the respective test pieces and the organoleptic values obtained as the degrees of pain in the organoleptic test, after normalization. Here, the normalization of the variables in Table 7 were performed based on the maximum value 0.95 and the minimum value 0.5 set in the shape variables in Table 5. The normalization in Table 8 was performed such that the maximum values and the minimum values of the organoleptic values, as well as, the inferred values before normalization are set at 1 and 0, respectively.

TABLE 7

Test piece no.		2-8	2-9	2-10	2-11	2-12	2-13	2-14
Before normalization	h (mm)	0.80	0.90	0.50	1.50	0.80	1.20	1.50
	θ (deg)	53.13	118.07	83.97	86.05	86.30	109.56	126.87
After normalization	h	0.32	0.41	0.05	0.95	0.32	0.68	0.95
	θ	−0.04	0.61	0.27	0.29	0.29	0.53	0.70

TABLE 8

Test piece no.	2-8	2-9	2-10	2-11	2-12	2-13	2-14
Degree of pain (organoleptic value)	0.00	0.85	0.05	1.00	0.59	0.94	0.89
Degree of pain (inferred value)	0.02	0.85	0.00	0.99	0.49	1.00	0.81

FIG. **7** is a graph showing test piece nos. and the degrees of pain in the inferred pain verification test.

As is clear from FIG. **7**, there was obtained a result that the inferred values as the degrees of pain measured by the pain inferring device **10** substantially coincide with the organoleptic values obtained as the degree of pain in the organoleptic test.

The pain inferring device **10** according to the present invention enjoys the following advantages:

(1) The pain inferring device **10** includes the input unit **11** for inputting shape variables (shape data) for specifying a shape, the neural network **15** learning the relationship between the input of the shape data and the output of the degree of pain to be given by a shape corresponding to the shape data to produce an input-output function indicative of the relationship between the input and the output, and the learning storage unit **14** for storing the input-output function. If shape variables are inputted through the input unit **11**, the main control unit **13** supplies to the output unit **12**, a degree of pain obtained from the neural network **15** based on the shape variables and the function. Thus, by inputting various kinds of shape variables to the pain inferring device **10**, the degree of pain associated with the shape variables can easily be inferred by the device **10** at the stage of designing. In other words, once the pain inferring device **10** learns degrees of pain, there is no need of preparing a test piece having a new shape for measuring the degree of pain thereof.

(2) Learning by the neural network **15** easily enables inferring of the degree of pain; and

(3) The neural network **15** produces an input-output function indicative of the relationship between known shape variables (shape data) as input values and the data on the degree of pain associated with the shape variables, as an output value, and if new shape variables are inputted to the pain inferring device **10**, the device **10** infers the degree of pain based on the input-output function. According to this inferring method, the degree of pain can easily be inferred.

It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or scope of the invention. Particularly, the present invention may be embodied in the following forms

The hierarchical neural network **15** may be replaced with an interconnecting neural network.

The hierarchical neural network **15** may have two or more intermediate layers.

The surface profile of the test piece is not to be limited to the ribs **20**, but the ribs **20** may be replaced, for example, with steps or protrusions. The protrusion may each have, for example, a truncated quadrangular pyramidal shape, a truncated conical shape or a hemispherical shape.

What is claimed is:

1. A pain inferring method, comprising the steps of:

learning a relationship between shape date as an input and a degree of pain, as an output, felt by a person when he or she touches a shape corresponding to the shape data;

producing an input-output function indicative of the relationship between the input and the output; and

inferring, based on an input of new shape data, a degree of pain according to the input-output function.

2. The pain inferring method according to claim **1**, wherein the learning step and the inferring step are performed using a neural network.

3. The pain inferring method according to claim **2**, wherein the learning step includes learning the relationship between the input and the output in accordance with a back-propagation algorithm using the neural network.

4. The pain inferring method according to claim **3**, further comprising the steps of:

inputting predetermined shape data and a predetermined degree of pain; and

terminating learning by the neural network, when an error between a degree of pain formed newly and the predetermined degree of pain reduces to a predetermined level or lower in the back-propagation algorithm.

* * * * *